Project No. A-075

SONIC METHOD FOR MEASURING THICKNESS OF NON-METALLIC MATERIALS

Technical Report

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for

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I. INTRODUCTION

This is a report on an investigation, conducted at [redacted] 25X1 [redacted] 25X1 into the feasibility of measuring, by means of ultrasonics, the thickness of non-metallic materials. In this investigation the following criteria were kept in mind:

1) The method must be capable of making the measurement without access to one side.

2) The method should be capable of covering a range from an inch to several feet.

3) The method used must be silent.

4) The equipment used should be portable.

In view of the first requirement, there are two methods to be investigated:

A. The first of those is the echo-pulse method, in which is measured the time required for an ultrasonic pulse to travel the length of the sample, undergo reflection, and return to the combined transmitter-receiver. The thickness can then be found, with the same accuracy to which the velocity of ultrasound in the material is known, by multiplying the velocity by one-half of the total travel time. The velocity need not be known or measured as such if a sample of the material is available for comparison of travel times, or if the measurement is repeated after removing a known thickness. In these cases a simple ratio calculation will give the thickness. For less accurate measurements an approximate value of the velocity can be used (e.g., for concrete the velocity of sound is approximately 4000 meters/second).

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B. The second possible method would involve the determination of the ultrasonic frequencies to which the object is resonant. If the thickness is any integral number of half-wave lengths at the frequency of excitation of a transducer in contact with the object, the object will take more energy from the transducer, which effect will be reflected by an increase in the power the transducer draws from the exciting oscillator.

II. DISCUSSION OF TECHNIQUES

Each of the above methods would have its advantages and disadvantages. Some of the advantages can be discovered by a simple consideration of the methods involved. Before considering these, the question of the frequency range in which the measurements are to be made should be discussed. There are some indications in the literature (12, 14) (numbers in parentheses will refer to references as listed in the appendix) that the absorption of compressional waves in concrete rises as a function of frequency above 20 kcps (kilocycles per second). It has been stated (14) that a 20 kcps ultrasonic wave will penetrate 50 feet of concrete, while a 100 kcps wave is limited to a penetration of about one foot. It would seem, however, that the range could be increased by increasing the power. For the moment, however, the calculations will be based on an allowable frequency range of 20 - 100 kcps.

If the echo-pulse method is to be used, a sufficient length of time, say at least five periods, must be allowed for the initial pulse to decay before the return pulse can be detected. At 20 kcps this time is 0.25 milliseconds and at 100 kcps this time is 0.05 milliseconds. During this time, in concrete, the leading edge of the pulse will have travelled

approximately 1.0 meter or 0.2 meter, respectively. Thus, the minimum measurable thickness would be 0.5 meter (20 inches) to 0.1 meter (4 inches) depending on the frequency used. The upper limit on distance would be determined by the ability to detect the reflected wave. The lower limit could be further reduced by electronically damping the wave after one period which would give a reduction by a factor of 5 or less by going to higher frequencies. The latter solution might then call for an instrument which would have two ranges at two frequencies.

The lower limit on distance for the resonance method would occur where the thickness of the object is one-half-wave length of the highest frequency available. This would occur, if 100 kcps were to be taken as the upper limit of the frequency sweep, at approximately one inch for concrete. By raising the upper limit of the sweep to 200 kcps, the minimum thickness would be reduced to 0.5 inch, and so on. Although this could more easily be done with one range here than in the echo-pulse method, a two range instrument might again prove more feasible. As in the echo-pulse method, the upper limit could be determined by the absorption and scattering in the concrete.

A word of warning should be added here about the variability of the velocity of sound in concrete. Even in sound samples of concrete the velocity may vary as much as 10 percent from sample to sample (9), depending on the amount of compacting or (although this is a small effect) the water content. For concrete that is old and beginning to deteriorate, the velocity may drop by 30 to 40 percent. Even in a single concrete sample, the velocity may vary by 5 percent in going from a surface to a center (9).

III. EXPERIMENTAL PROGRAM

A preliminary attempt to solve the problem through the use of commercially available equipment was the obvious first step. Should this approach succeed, it would save the time and labor required for the design and construction of the necessary transducers and associated electronic equipment. The unit chosen for these tests was the Sperry Reflectoscope, Type UR. One of these units was rented from Sperry Products, along with one each of the one mcps (megacycle per second), the 5 mcps, and the 10 mcps associated transducers. Concrete samples, 7/8ths of an inch in diameter and having lengths of from approximately 1/4 inch to 6 inches, were obtained from the Nuclear Physics Section.

No reflected waves were detectable at any of the three frequencies. This could have been due to;

1) Poor coupling between the transducer and the concrete sample, which would mean that the introduction of the energy into the concrete would be poor, as well as the reception of the reflected energy;
2) Excessive absorption or scattering of the energy in the concrete;
3) Poor reflection at the far end of the concrete sample, and
4) Inadequate power.

With regard to the question of coupling, it was obvious that some measure of contact was made, for the loading of the transducer due to the contact could be observed in the change of shape of the initial pulse envelope. Various methods of coupling were tried; including oil, water, glycerine, water and glycerine (each in a thin film between the transducer and the sample), and the same films with the additional insertion of a small rubber balloon containing oil, the transducer being forced down to

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place the oil under pressure. In no case was any reflected wave observed.

It is immediately obvious that one should expect a large amount of scattering in the concrete at the frequencies used, for the size of the pebbles in the sample are of the same order of magnitude as the wavelengths used. Moreover, although no complete set of measurements to show this were found in the literature, there is some indication that the attenuation rises as a function of frequency above 20 kcps. With the acquisition of two 0.5 mcps transducers and a second 1.0 mcps transducer for the Reflectoscope, it was possible to attempt to measure the absorption and scattering as well as the velocity. This was done by driving one of the transducers with the Sperry Reflectoscope and using the second transducer, placed at the other end of the concrete sample, as a receiver. The delay time due to the travel and the amplitude of the signal at the receiving transducer were observed on a Tektronix 532 oscilloscope which was triggered by the pulse to the transmitting transducer. By these measurements it was hoped to be able to determine the absorption and the velocity of the ultrasonic wave in the concrete sample.

The velocity was found to be 4000 meters per second (1.60×10^5 inches per second, 13,300 feet per second) for both the 0.5 mcps and the 1.0 mcps waves. The voltage developed at the receiving transducer was plotted, in several different ways, as a function of the intervening length of concrete. No simple relation, which would hold over the range of lengths used, was found between the two variables. It is believed that this was because of the small cross-sectional area of the sample, due to an effect that will be explained below. The experiment was also tried using a 100 kcps input to the transducer, with similar results.

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The attenuation measurements were repeated using a frequency source which was variable from 20 cps to 200 kcps. In the region from 20 kcps to 200 kcps, a plethora of peaks was found in the transmission versus frequency curve. However, these resonances were found to be independent of the length of the sample tested or the particular transducers used. It is believed that these resonances are due to higher modes of the cylinders, i.e., waves which are not plane longitudinal waves down the cylinder. This, along with the possible presence of waves along the surface, is the probable explanation of the failure to obtain reasonable attenuation curves at the higher frequencies. It is felt that these problems will disappear with the use of samples and transducers of larger cross-sectional areas.

A few tests were also made on other materials besides the metals for which the Sperry Reflectoscope was designed. Visible reflections were obtained in a six inch piece of granite and in a one inch thick clay tile. These results would indicate that any method that would be adequate for measuring the thickness of concrete walls would work on other denser more homogeneous mineral building materials.

IV. CONCLUSIONS

At first glance, the results of the tests on concrete with the Sperry Reflectoscope would seem to hold little hope for success. More careful examination, however, indicates that the problems can be solved, an indication that is born out by results reported in the literature. For example; in England, G. Bradfield has successfully measured the thickness of concrete in airplane runways by an echo-pulse method. His paper (3)

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describing this work is not available to the writer at the present time (it has been ordered), but the basic design of the transducer used is shown in another paper (4). Again, for years one or another type of sonic or ultrasonic method has been in use for non-destructive testing of concrete. Recently, Leslie and Cheesman (13, 14) have reported on a portable unit capable of sending an ultrasonic pulse through 50 feet of concrete in dams and detecting it at the far end. Jones (8; see also 7, 9, 10) has reported on similar work for shorter distances in concrete roads.

Because some of the references are not available [redacted] 25X1 (two of the unavailable references are on order) and because of the necessary incompleteness of the experimental investigation to date, it is impossible to completely describe, at the date of this report, all of the final properties of the equipment necessary for thickness measurements. However, from the preliminary experiments made at [redacted] and from the 25X1 results to date of the literature survey, the following statements may be made:

1) The objectives outlined in the introduction can be met.
2) The frequency used will be in the range from 20 kcps to a maximum of 200 kcps.
3) Larger transducers will have to be used, probably being made of barium titanate ceramics and having a transmitting area of several square inches.
4) A more thorough investigation is needed to determine the relative merits of the echo-pulse method and the resonance method, although at present the echo-pulse method seems to have more advantages,

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The above statements, therefore, show a promising solution to this problem by the application of sonic techniques.

Respectfully submitted,

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APPENDIX

1) R. V. Band: Schweiz. Bauztg. 71 (38), 554 (Sept., 1953).

2) G. Bradfield: Electronic Engineering 24 (295), 390, (1952).

3) G. Bradfield: Acoustica 4, 121, (1954).

4) G. Bradfield and E. P. G. Woodroffe: Nat. Phys. Lab., Rep. No. Phys. U5, Feb. 1953.

5) K. Eisenmann and G. Steinkamp: Beton U. Stahlbeton, 49 (2), 36 (Feb. 1954).

6) R. H. Elvery: Mag. Conc. Res. 7, 161, (Nov. 1955).

7) R. Jones: Research, Lond., 1, 383 (1948).

8) R. Jones: Mag. Conc. Res., 1, 31, (Jan. 1949).

9) R. Jones: Mag. Conc. Res., 2, 67, (June, 1949).

10) R. Jones: Mag. Conc. Res., 7, 97 (1955).

11) R. Jones and E. N. Gatfield: London HMSO, 1955, Road Research Technical Paper no. 34.

12) W. Kuhl and H. Kaiser; Acoustica, 2, 179 (1952).

13) J. R. Leslie and W. J. Cheesman: Proc., Amer. Concrete Inst. 46,17, (1949).

14) J. R. Leslie: Am. Soc. Test. Mat. Tech. Pub. No. 101, p.104 (1951).

15) K. Wesche: Beton U. Stahlbeton, 48, (5), 116 (May, 1953).

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